with compliments

R.V. Dingle

The continental shelf between Cape Town and Cape Agulhas

R. V. Dingle, I. Gerrard, R. I. Gentle

and E. S. W. Simpson

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SUMMARY

Continuous seismic reflection profiles across the continental shelf between Cape Town and Cape Agulhas reveal large sub-bottom basement features formed of Lower Palaeozoic and older rocks partially overlain by Mesozoic (Cretaceous) and Caenozoic sediments. One of these basement features, the Agulhas Arch, has been traced for over 70 miles (130 km) offshore and forms an elongated upwarp around which the younger sediments lap. During Cretaceous and Tertiary times the continental shelf between Cape Town and Cape Agulhas was built strongly upwards and outwards, although sedimentation was interrupted in late Cretaceous/early Tertiary times by a period of tilting and, locally, folding and igneous intrusion. Quaternary sediments blanket most of the middle and outer shelf, but are only locally of moderate thickness.

SOMMAIRE

Des profils continus obtenus par la sismique réflexion à travers la plate-forme continentale entre Le Cap et le Cap des Aiguilles montrent l'existence de grands traits au sousbassement formés de roches du Paléozoïque Inférieur et de roches plus anciennes surmontées en partie par des sédiments Mésozoïques (Crétacés) et cénozoïques. Un de ces traits du socle, la voûte des Aiguilles, a été tracé plus de 130 km au large et il forme un ploiement prolongé autour duquel se trouvent les sédiments plus récents. Pendant le Crétacé et le Tertiaire la plate-forme continentale entre Le Cap et le Cap des Aiguilles a développé fortement en montant et vers l'extérieur. Cependant la sédimentation était interrompue pendant le Crétacé postérieur et le Tertiare antérieur par une période de relèvement et localement, de plissement et d'intrusion ignée. Des sédiments quaternaires couvrent la plupart de la plate-forme centrale et extérieure, mais ils n'atteignent que par endroits à une épaisseur moyenne.

ZUSAMMENFASSUNG

Ununterbrochene seismische Reflexionsprofile querüber dem Kontinentalschelf zwischen Kapstadt und dem Nadelkap zeigen grosse aus Unterpaläozoischen und älteren Gesteinen gebildeten unterbodenbasische Eigentümlichkeiten, die teilweise von mesozoischen (kreidigen) und känozoischen Sedimenten überlagert sind. Man hat eine dieser basischen Eigentümlichkeiten, die Nadelbeulung, in der Küstennähe, mehr als 130 km, entdeckt. Diese Beulung bildet eine verlängerte Beule, und um dieser Beule legen die jüngeren Sedimente. Während der Kreidezeit und des Tertiärs wurde der Kontinentalschelf zwischen Kapstadt und dem Nadelkap kräftig aufwärts und auswärts gebildet, obgleich eine Kippungszeit und eine örtliche Faltungs- und Vulkanisch-intrusion in der Spätkreidezeit/dem Frühtertiär Sedimentation unterbrochen haben. Quartärsedimente deckem den meisten Schelf, aber sind nur örtlich von mittler Dickheit.

The continental shelf between Cape Town and Cape Agulhas

R. V. DINGLE, I. GERRARD, R. I. GENTLE and E. S. W. SIMPSON

INTRODUCTION

The seismic survey upon which this paper is based was carried out in June 1969 as part of the current investigation of the continental margin around southern Africa. The equipment used was an E.G. & G. Sparkarray system with a power output of 1000 joules. Seismic traverses shown in Fig. 1 are superimposed upon a bathymetric chart of the western Agulhas Bank compiled during the course of earlier bathymetric and bottom-sampling work. Nearshore, bottom samples have provided invaluable checks on the interpretation of the seismic records, particularly with the identification of Cretaceous and Tertiary horizons which have largely been extrapolated from records obtained east of Cape Agulhas (see Dingle, in press, a).

Isochrons measured in milliseconds one-way-time from a sea level datum are used to represent basement structures in Fig. 2.

BATHYMETRY AND GENERAL REMARKS

Although the general form of the continental margin around South Africa has been discussed by Simpson (1966), no detailed bathymetric studies of the shelf between Cape Town and Cape Agulhas have been previously published. The bathymetry of the eastern part of the upper Agulhas Bank has been discussed by Dingle (in press, a). The most striking morphological variation that is apparent on moving from the eastern to the western part of the Agulhas Bank is an increase in the depth of the shelf break from 110-160 m east of longitude 20° 30'E to about 270 m in the south-east of the area discussed in this paper, on the western side of the Bank (Fig. 1). This change occurs over a structural divide, called here the Agulhas Arch, which is discussed in more detail below. Moving north-westwards, the depth of the shelf break remains in the region 270-280 m to the vicinity of Cape Point, where it is anomalously shallow (200 m), poorly defined, and the shelf itself narrows from between 25-30 miles (46-55 km) to about 12 miles (22 km). North-west of this area a further deepening of the shelf takes place and west of the Cape Peninsula it occurs at about 350-380 m. Although not fully understood, these variations in depth of shelf break, which are accompanied by fluctuations in the width of the continental shelf, can be correlated with distinct changes in the gross sub-bottom geological structure, and in particular with the form of the pre-Mesozoic basement morphology.

The morphology of the shelf itself is relatively featureless, due to a fairly extensive Quaternary sediment cover, except for a continuous nearshore rocky zone and a large shoal area extending south-south-east of Cape Agulhas over the Agulhas Arch.

GEOLOGICAL RESULTS

On the seismic records three main rock sequences can be distinguished (Figs. 3 and 4), which are separated by major unconformities. These are the basement, Mesozoic, and Caenozoic sequences, and the distribution and structures of these will be dealt with in turn.

Basement

'Basement' is used here to denote rocks of pre-Mesozoic age. Onshore, the basement rocks consist of Palaeozoic Cape Supergroup quartzites (Table Mountain Group) and shales (Bokkeveld Group), with areally less important outcrops of pre-Cape granites and low-grade metamorphics (Malmesbury Group). These rocks are strongly folded and faulted in the Cape Fold Belt, which displays a virgation zone just east of Danger Point; north-east trends north-west of Danger Point and east to south-east trends to the east. Offshore continuations of individual structures are poorly known, but off Danger Point and Struys Point prominent bathymetric and sub-bottom basement ridges appear to indicate the seaward extension of onshore fold structures. By plotting isochrons to the basement, three major features have been delineated in the sub-Mesozoic topography between Cape Town and Cape Agulhas (Fig. 2): 1. the Cape Peninsula basement feature (Cape Town to Rocky Bank); 2. Rocky Bank to Cape Agulhas basement zone; and 3. the Agulhas Arch.

Of these, the latter is the most clearly defined and consists of a north-west trending elongated upwarp of basement rocks lying to the south-south-east of Cape Agulhas. The exact configuration is not known, but data suggest that in the south-east it is a roughly symmetrical feature on either side of which the sub-Mesozoic basement plunges relatively steeply beneath the overlying sediments. A median bathymetric (and possibly also structural) low lies along the axis of the Arch between two flanking ridges. Towards the north-western end the cross section

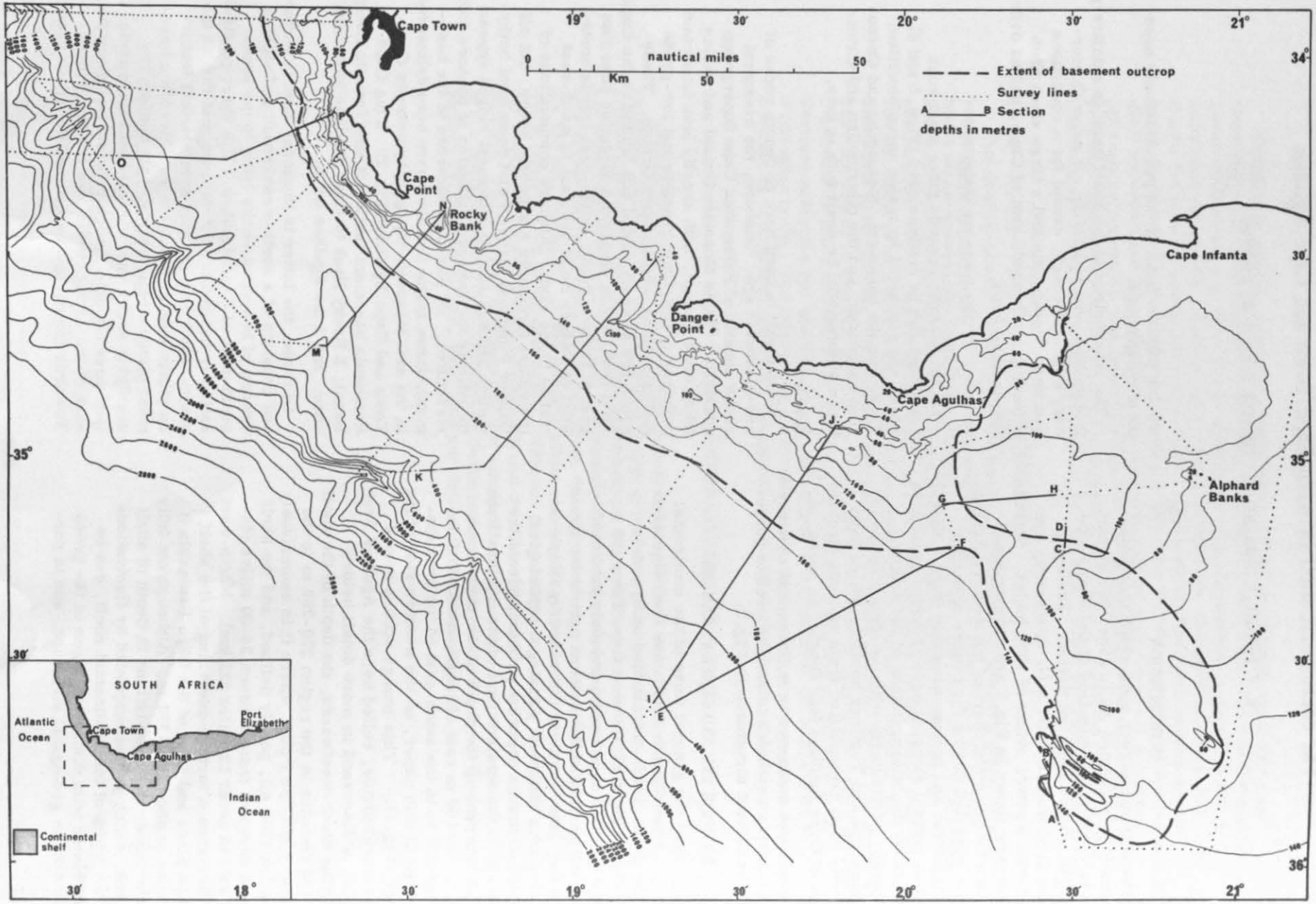

Fig. 1. Bathymetry and survey tracks. Depths in metres. Sections A-B to O-P are shown in Figs. 3 and 4. Inset shows location of area studied.

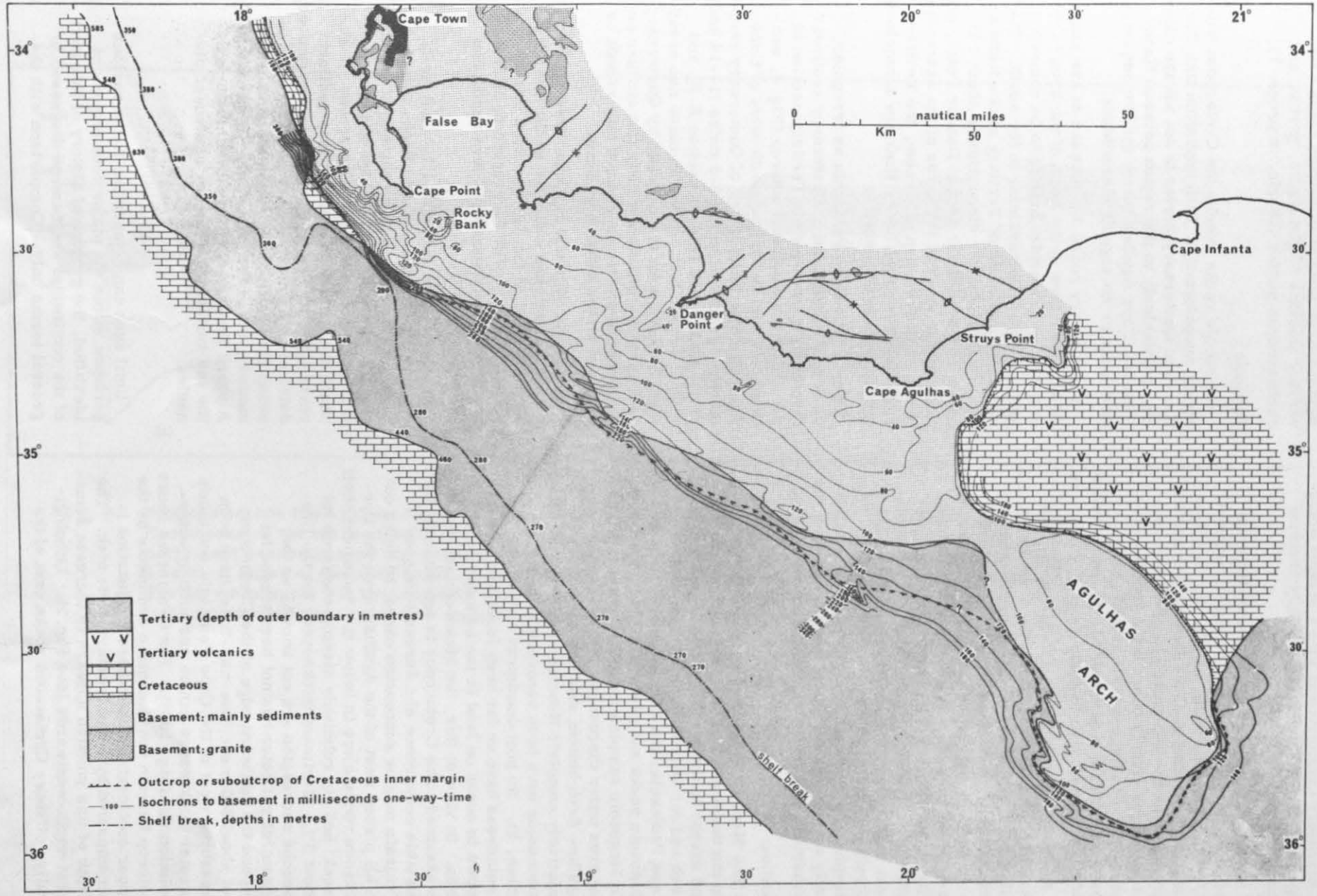

Fig. 2. Outline geological map. Datum for isochrons to the basement is sea level.

is markedly asymmetrical with a steeply plunging northern flank and a more gently shelving south-western flank (Fig. 3).

Between Cape Agulhas and Rocky Bank the basement forms a wide ledge (Fig. 4, sections I-J and K-L), with local, small, high features such as the extension of the Danger Point folds. Beyond about the 100 msec isochron the basement plunges steeply beneath the younger sediments, this 'basement shelf break' being characteristically accompanied, on the landward side, by a small high feature.

North-west of Rocky Bank (which is a large basement boss detached from the Cape Peninsula by a steep depression), along the western side of the Cape Peninsula feature, the basement ledge is narrow and it plunges to seaward very steeply beneath the overlying sediments (Fig. 4, sections M-N and O-P). Topographically, it is quite irregular, with a steep east-west valley-like depression crossing it about 10 miles (6 km) north-west of Cape Point. The steepness of the western edge of what is essentially an unfolded basement feature suggests the possibility of north-west trending fault control.

Mesozoic

The Mesozoic and Caenozoic sediments overlie the basement with a strong unconformity, and except on the northern side of the Agulhas Arch and for two small patches west of the Cape Peninsula, the Caenozoic oversteps the Mesozoic rocks and rests directly on basement. No Mesozoic samples have been collected from the area under discussion, but east of the Agulhas Arch bottom samples suggesting a relatively complete Neocomian to Maastrichtian succession have been recovered (Dingle, in press, b). No post-basement rocks older than Cretaceous have so far been found and none are known to occur on land in the adjacent coastal area. In view of this, the Mesozoic succession is assumed to be Cretaceous in age although the possible occurrence of a Jurassic or even Triassic marine succession cannot be ruled out. In all places west of the Agulhas Arch the Cretaceous rocks come in below the 'basement shelf break' and dip relatively steeply seawards (at about 2°). Maximum thicknesses for the Cretaceous succession are not known, as the basement reflector has not been traced far beyond the landward edge of the Cretaceous, but about 200 msec (one-way-time) have been measured west of the Cape Peninsula and much greater thicknesses can be assumed by extrapolation (Ludwig, 1968). The Cretaceous rocks outcrop beneath the Caenozoic sediments on the upper continental slope where the junction is accompanied by a small bathymetric nick. The depth of this junction appears to increase somewhat north-westwards (see Fig. 2). Lithologically, offshore Cretaceous rocks east of the Agulhas Arch consist of marine clays with varying amounts of glauconite, pyrite, and carbonaceous matter (Dingle, in press, b).

Caenozoic

Caenozoic rocks overlie the Cretaceous with strong unconformity. Differentiation into Tertiary and Quaternary series is not always clear cut, particularly in the region between Rocky Bank and Cape Agulhas where the two sequences have little or no angular discordance.

The Tertiary rocks dip seaward at low angles (1° or less), dips in the north of the area (west of the Cape Peninsula) tending to be somewhat greater than those obtaining in the south. The maximum thickness of Tertiary rocks found so far in the area under discussion is about 130 msec (one-way-time) west of Danger Point, and although the average thickness of the succession is not much less than this value, the Tertiary rocks south-west of Rocky Bank are anomalously thin (less than 50 msec).

West of the Cape Peninsula an irregular, thick prograding lens of Quaternary sediment discordantly overlies the Tertiary section at the foot of the basement outcrop (Fig. 4, sections M-N and O-P), and south-west of Cape Agulhas a flat-lying wedge of Quaternary sediment progrades to within 6-8 miles (11-14 km) of the shelf break (Fig. 3, section E-F, and Fig. 4, section I-J). Between these two areas the Tertiary rocks are overlain by Quaternary sediments but because of their flat attitude and lack of bathymetric expression they cannot be resolved on the seismic records.

Only Upper Miocene bryozoan/foraminiferal limestone has been collected so far from the Tertiary west of the Agulhas Arch (Siesser, in press), but east of it Palaeocene to Miocene marls and limestones have been recovered (Dingle, in press, a).

On the eastern side of the Agulhas Arch, roughly between the Alphard Banks and the basement outcrop, a large number of small early Tertiary intrusive plugs of aegirine-trachyte pierce the folded Cretaceous rocks, which are here devoid of Tertiary sediment cover (Dingle, in press, a). These intrusions, dated at 58 ± 2 million years generally do not reach the sea floor except as insignificant mounds, but in the immediate vicinity of the Alphard Banks they reach to within 20 m of the sea surface as a cluster of slender pinnacles.

CONCLUSIONS

Until ages can be ascribed to the various horizons within the major rock sequences identified, the geological history of this part of the continental shelf can be discussed in general terms only. Comparison with the

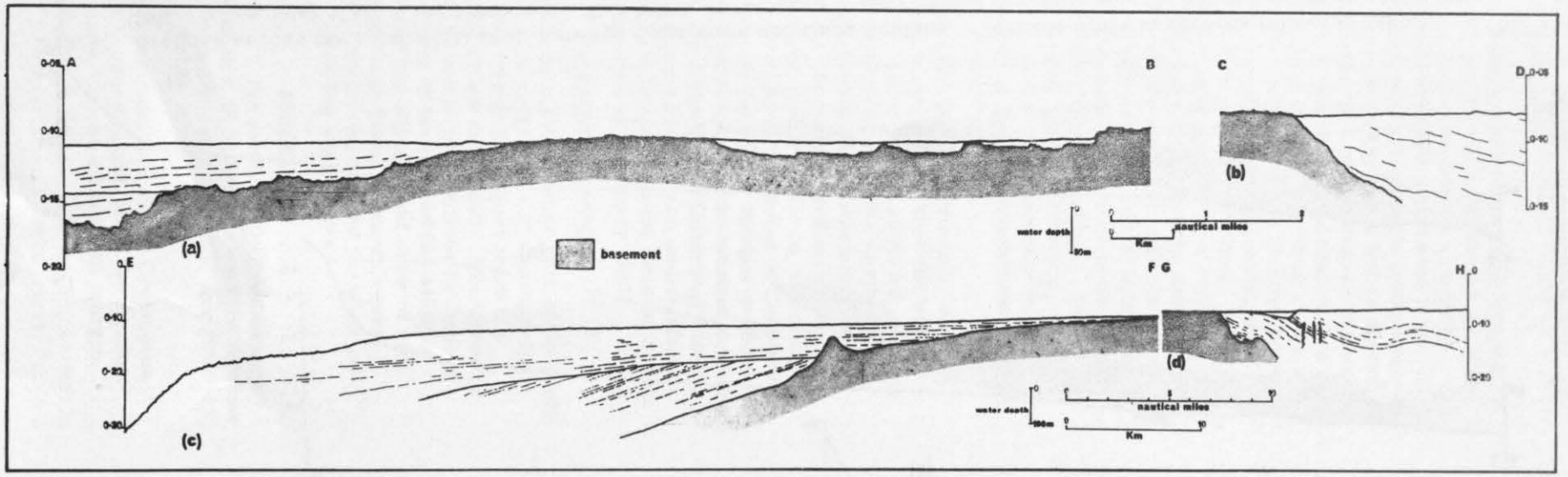

Fig. 3. Sections across the Agulhas Arch. Vertical scale in seconds (one-way-time). (a), southern edge (note Tertiary overlying Cretaceous on the extreme left). (b), northern edge. (c, d), profiles E-F, G-H are essentially a continuous south-west to north-east section across the western part of the Agulhas Arch. A prograding Recent sediment wedge reaches to within 8 nautical miles of the shelf break. It produces a small but distinctive rise in the sea floor landward of the slightly uneven Tertiary exposure, but the boundary with the underlying Tertiary cannot be confidently resolved. Note folding and faulting (with intrusives?) of Cretaceous on north-eastern flank and the north-south asymmetry of the Arch.

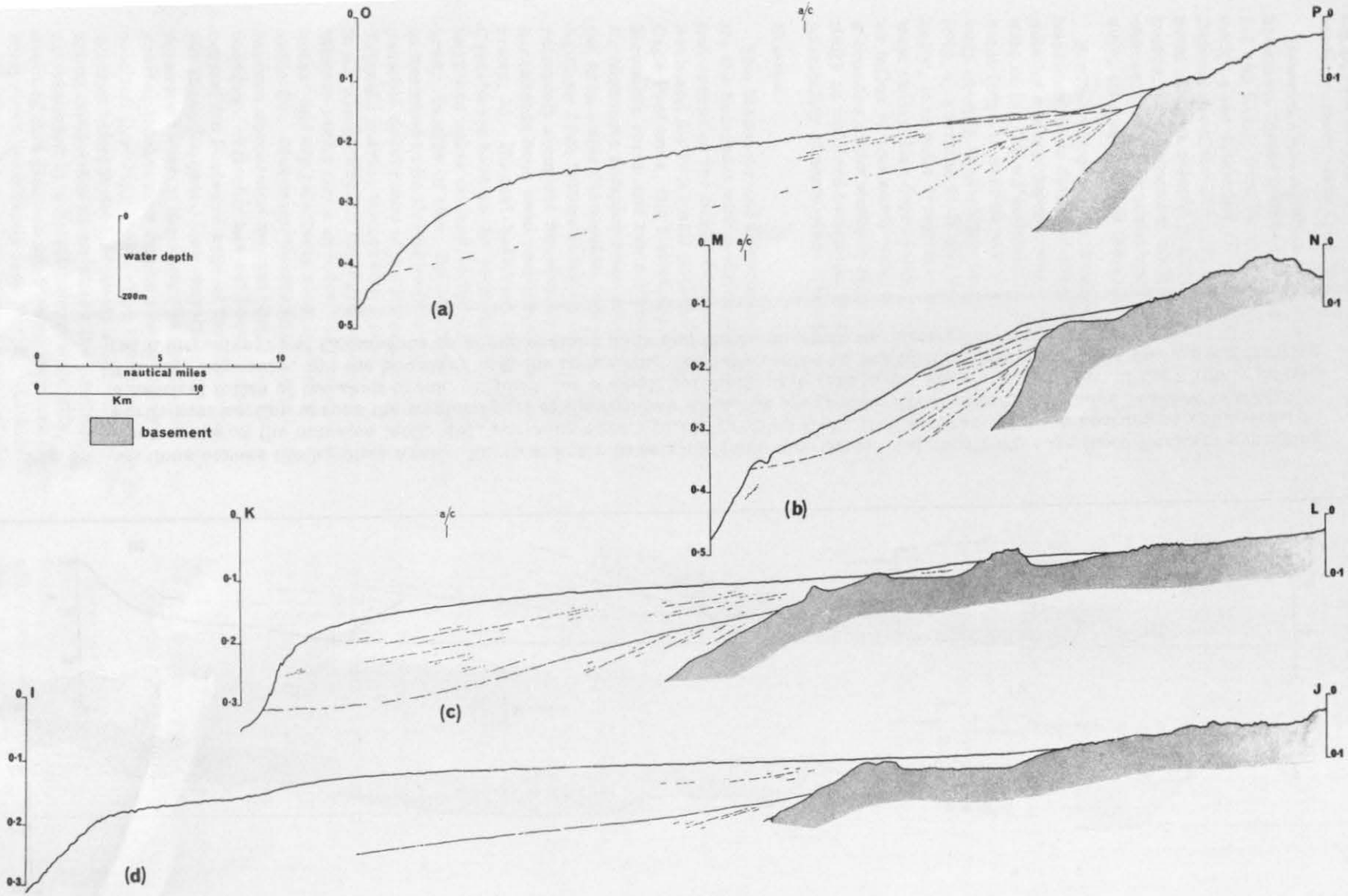

Fig. 4. Sections across the continental shelf between Cape Town and Cape Agulhas. Vertical scale in seconds (one-way-time). (a), section west of the Cape Peninsula. The basement outcrop is narrow and descends steeply beneath younger sediments. A thick Recent sediment wedge progrades seawards from the foot of the basement outcrop. (b), section west of Rocky Bank. The shelf is anomalously narrow with steeply dipping Cretaceous and Tertiary sediments and a thick Recent wedge at the foot of the basement outcrop. (c), section west of Danger Point. The basement is a wide ledge beneath the thin Caenozoic cover. Recent sediments are not readily differentiated. (d), section west of Cape Agulhas. This is similar to (c). The prograding Recent sediments reach to within 6.5 nautical miles of shelf break, and are accompanied by a slight bathymetric feature (cf. profile E-F, Fig. 3).

area east of Cape Agulhas (described by Dingle, in press, a) is helpful.

The Cape Supergroup sedimentary succession was folded during the early Mesozoic and then subjected to a prolonged period of erosion. Although marine Jurassic sediments occur in Madagascar the earliest apparent post-orogenic sediments were laid down along the southern Cape coastal area as a transgressive sequence in late Mesozoic (Lower Cretaceous) times and rapidly filled deep coastal intermontane basins with terrestrial, estuarine and marine deposits. During the Cretaceous the continental shelf was built strongly upwards and outwards, but sedimentation must have ceased in late Cretaceous or earliest Tertiary times and the sediment pile tilted seawards with folding in some areas. This was possibly accompanied by uplift and erosion, and at least in the area north-east of the Agulhas Arch, tectonic activity, followed or accompanied by igneous intrusion, took place. These events were possibly contemporaneous with the Laramide movements in other parts of the world.

Following these earth movements, early Tertiary seas transgressed over the western Agulhas Bank, which slowly subsided. During this phase of sedimentation the Agulhas Arch was tilted downwards on its western flank, where at least 100 msec of sediment accumulated, whilst remaining stable on its north-eastern flank where no thickness of Caenozoic sediments can be detected. Sample evidence suggests that little or no sedimentation occurred between Upper Miocene and Quaternary times and that during the Pleistocene sedimentation recommenced with the vigorous erosion of soft sediments exposed on the upper shelf.

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R.V. Dingle, R.I. Gentle and E.S.W. Simpson,
SANCOR Marine Geology Group, Department of Geology, University of Cape Town,
Rondebosch,
South Africa.

I. Gerrard,
Department of Mines (Geological Survey),
Marine Geophysical Unit.

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